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A

TREATISE

ON THE

ORIGIN AND COMPONENT PARTS

OF

THE STONE

IN THE URINARY BLADDER.

BEING THE SUBSTANCE OF THE GULSTONIAN LECTURES,
READ AT THE COLLEGE OF PHYSICIANS
IN THE YEAR 1790.

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TO THE

PRESIDENT AND FELLOWS

OF

THE COLLEGE OF PHYSICIANS,

THIS TREATISE

IS VERY RESPECTFULLY INSCRIBED,

BY THEIR MOST OBEDIENT SERVANT,

WILLIAM AUSTIN.

PART I.

On the Formation, Appearance, and Situation, of the STONE.

IT has generally been understood, that the stone in the urinary bladder is produced from something secreted with the urine. Though it is well known, that the sides of the cavities destined to receive the urine, and convey it out of the body, are constantly lubricated with mucus; yet, so far have we been from applying this knowledge to the explanation of this disease, that the mixed fluid, consisting of urine secreted by the kidneys, and of mucus discharged from the vessels through which it passes, is most commonly considered simply

as urine. When the opinion prevailed that the stone was composed of earthy particles, an opinion which has not till lately been rejected, it was conceived that the urine often abounded with these particles, sometimes to such a degree that they spontaneously precipitated, and collecting together, formed a stone; at other times, that some foreign body afforded them a nucleus upon which they crystallized; or that they were cemented together by mucus. Later experiments have shewn, that only a very small portion, not exceeding one two-hundredth part of the stone is earthy; and that it consists in a great measure of matters which are volatile in a moderate heat. A sublimate of a peculiar nature has been found to arise during the application of heat to the stone. No sooner was this discovery made, than the urine was explored, and the sublimate was supposed to be found there. It was concluded, from experiments made on a few calculi, that they all contained this sublimate; and the operation

of remedies as solvents was accounted for by the action of alkaline substances upon it.

The inquiries and observations, which I have been able to make upon this subject, have led in many points to very different conclusions. The main result of these inquiries has been, that the stone is formed generally in very small part, and often in no degree whatever from the urine as secreted by the kidneys, but chiefly from mucus produced from the sides of the different cavities through which the urine passes: that certain stimuli applied to the whole or part of the bladder, give occasion to the production of calculi from the whole or part affected: that the proximate cause of the (disease or) stone is a morbid state of those membranes, and consequently of their secreted juices: that the operation of various remedies for the stone depends on their immediate action on those membranes, by correcting their secretion, or diminishing their irritability: that the sublimate of Scheele is not found in many

calculi: that the urine in general does not contain it: that this sublimate may be resolved into prussic acid, phlogisticated air, and volatile alkali, or by particular treatment may be in a great measure converted into heavy inflammable air: that solvents have different effects on different calculi; and that this difference in their operation depends chiefly on the presence or absence of the calculous sublimate.

It is scarce necessary to premise, that any hard body found in the bladder, kidneys, or ureters, is considered as a stone. Its hardness is in practice its only character. Any substance which jars or sounds against his instruments, a surgeon determines to be a stone. This appellation is universally applied to hard substances found in glands, or in their excretory ducts. They were called calculi, from a mistaken idea of their being calcareous earth. This is so far from truth, that not only the urinary calculi, but all other indurated substances of a morbid kind, as stones in the gall-bladder, bezoars,

stones in the prostrate gland, pulmonary stones, tartar of teeth, and all other concretions of this nature, which I have examined, contain a very small portion of calcareous earth. The only morbid concretion which I have found to consist of a calcareous basis, is the hard substance sometimes formed between the coats of blood-vessels, which resembles bone in its appearance, and in its composition.

It is not uncommon to conceive the stone as consisting principally of a peculiar hard substance as a basis, the particles of which are furnished by the urine, and of a cementing substance, which connects these particles. This theory is the offspring of the exploded doctrine of earth composing the stone. There is no reason for supposing urine the source of one part of the stone, and mucus of another. It is possible that the stone may derive something from each, but experiment affords no distinction of hard basis and cement; all the parts of the stone are equally stone: indeed, ana-

lysis shews, that it is chiefly hardened mucus, or inflammable matter, whether derived from the one fluid or the other.

Consider these two fluids, and the situation of the stone *à priori:* the urine a transparent perfect fluid, not subject to evaporation in the bladder, or to change of temperature; the mucus an opaque viscid kind of substance, approaching in some degree to a solid, and in some cases actually possessing solidity, even before it leaves the secreting surface: consider the stone either surrounded by these fluids, or pressed upon by the sides of the bladder, ureters, or kidneys, from which one of them is discharged; the stone and mucus, each of them heavier than urine, and consequently disposed to sink together to the depending part of the bladder, or other containing cavities; and the stone there remaining in close contact with more or less of mucus, after the last drops of urine are from time to time expelled: Let any man reflect upon these circumstances, and then say, whether he

thinks it possible, that the mucus should not have a principal part in the formation of the stone.

The disposition of the mucus of the bladder to harden both in and out of the body, may be shewn from actual observation.

De Haen " collected the urine of various " people afflicted with the stone, and hav- " ing poured off the clear urine, placed the " mucus in the open air. This mucous " fluid soon dried, and afforded sometimes " two, sometimes three drachms of stony " matter, moulded to the figure of the ves- " sel. Whether the urine of every cal- " culous person, without exception, exhi- " bits this appearance, he does not presume " to say."

He further observes, " that the urine of " many calculous persons abounds with an " earthy matter, which, in some sooner, in " others later; in some, from the urine it- " self upon its standing, in others, from " the mucus alone preserved separately

" from the urine, forms a kind of chalk, " and stones." *

I separated the mucus of a man, who had discharged several small white stones, from his urine, and immersed in the mucus, and in the filtered urine, equal pieces of a stone which had been taken from another person. In the space of four or five days I took these pieces of stone from the mucus and urine, and dried them. Each of them had acquired a new surface; that immersed in mucus resembled in colour the stones which

* De Haen, Ratio Medendi, vol. ii. p. 74. " Urinas va- " rias calculo laborantium collegi, gluten inde separavi, et " in aere aperto, limpidâ urinâ abjectâ, posui. Brevi glu- " tinosum hoc exaruit, et drachmas duas aliquando drachmas " tres materiæ limpidæ, ad figuram vasis formatæ, exhibuit. " An autem non detur calculosus quin idem phænomenon in " ejus urina adpareat, nondum assero."

And p. 75. " Experimenta, ut vidimus, docent in urina " calculosorum multorum copiosam materiam terrestrem " haberi, quæ in his cito, in illis tardius; in quibusdam ex " ipsâ urinâ stagnante, in aliis duntaxat ex asservato post " effusam urinam glutine, cretam quandam, lapillosque " formet."

were discharged by the man, from whom I had it; that in urine was covered with a darker coloured crust: That in mucus had increased in weight more than that in urine, though the quantity of mucus was at least ten times less than that of urine. I separated the mucus of the same man very carefully from urine, and from every particle of gravel which adhered to it: I then dried it with a gentle heat: In drying, it hardened, and assumed an appearance of small whitish shining crystals, which could in no respect be distinguished from the calculi of the same person. I subjected the dried mucus and stone to a chemical examination, as will appear hereafter, and found them to agree in several properties.

An induration of the mucus was often observed to take place by those who were using Mrs. Stephens's medicines. I was favoured by Mr. Woollaston with the perusal of a manuscript containing a very exact description of a calculous case, during a long trial of soap and lime-water. The

patient himself was the author. He had been taking these medicines, simply or combined, for several years; when he observed that, on September the 10th, 1763, he discharged, to use his own words, "a "pretty deal of white sediment, resembling "soft soap, which lay at the bottom, and "adhered to the sides of the glass; but no "scales, or gravel. This being left for a "few days in the glass, concreted into a "stone-like substance, which seems strange. "I now took more than half an ounce of "soap *per diem*." In a few days after this he is troubled with more pain and irritation, succeeded by a discharge of blood, which obliged him to desist from his solvents, and to have recourse to demulcent medicines. He then proceeds—"In Oc-"tober I renewed the lime-water and soap, "but in less quantity, and found myself "easier, and my water clear. On in-"creasing the soap, the 9th and 10th day, "more of the former soapy appearances, "which being left in the glass became hard,

" even with a constant change of urine, and " now not knowing what to make of it, I " was discouraged from any further in- " quiry."

If we examine the surface of a recently extracted calculus, we generally find it smeared more or less with mucus; and upon separating or breaking its superficial parts we see strings of mucus almost like membranes adhering to them. It has sometimes happened that mucus upon the surfaces of stones has been so dense and copious as to prevent their giving the usual resistance to an instrument. In page 296, vol. v. Van Swieten quotes a very singular case of this kind, in which many surgeons, and among others Fallopius, were prevented from finding a stone by a thick covering of mucus. The stone incrusting a pin, which Morgagni himself observed, was covered with a thick coat of mucus.

A case will be described hereafter, in which the mucus of a man who had undergone an operation in the urethra, ac-

quired a solid form both in the bladder and after it was discharged.

In the Acts of the Royal Academy of Sciences at Paris, 1740 and 1741, several cases of this kind are related by Morand.

The two following cases recited by De Haen, deserve particular notice. "On the "13th of July of the present year, I "was consulted by a man who at the "age of thirty-four had been a real martyr "to the stone for eight-and-twenty years. "Though he has not parted with stones, "he never passes his urine without heat, "and without an admixture of red sand. "He has discharged for a long time, at in-"tervals, and for the space of eight years "more frequently, a very copious white "mucous substance, which left to itself "for a short time, forms friable and white "stones. Thus it happens when he keeps "himself still: but if he is in motion on a "journey, or in any other way, he voids "a dark-coloured urine, such as is usual

" in strangury. No person can distin-
" guish these stones, of which I have abun-
" dance, from pieces of chalk of different
" sizes. It is incredible how much this
" miserable sufferer was relieved within the
" space of a month by uva ursi, and that
" from the time that he began it."

" A calculous boy, from the Hague, was
" taking the celebrated English remedy of
" Mrs. Stephens." De Haen here describes that complicated medicine, and then proceeds. " We saw this boy, to the great joy
" of his parents, daily discharge white, stony
" or calcareous fragments, of such a form,
" that they appeared like scales of a stone,
" throwing off its superficial coat. But
" though this kind of matter was copiously
" discharged for a long time, yet the symp-
" toms of the stone were not mitigated
" thereby, nor did the stone appear to be
" diminished. Thus, after a large box full
" of these scales had been collected, the
" boy was obliged to undergo lithotomy,

" and a large stone was extracted from " him."*

* De Haen, vol. ii. p. 70—71. " 13 Julii hujus an- " ni ad me venit vir 34 annorum, qui per 28 annorum " spatium verus lithiaseos martyr, cum ardore nunquam " non minxit rubram arenam, calculos autem nullos. " Evacuavit subinde olim, et nunc sæpius ab octo retro " annis copiosissimam albam glutinosam materiem, quæ " pauculo tempore sibi relicta friabiles format albidosque " lapillos. Et hæc quidem in quiete. At si corpus in " itinere aliove modo movet, urinam fuscam, ac stran- " guriosam deponere solet. Lapillos hos, quorum copiam " habeo, diceret quis cretæ albæ majora esse minoraque " frusta, ad figuram demum vasis in quo urina servatur " formata. Incredibile quantum miserrimus ille intra men- " sis spatium uva ursi mutetur, idque jam ab ejusdem " initio."

" Calculosus puer Hagæ Batavorum utebatur famoso " Anglorum remedio Joannæ Stepfens dicto.—Videbamus " hunc puerum magno cum parentum gaudio, cum urina " quotidiè emingere fragmenta alba, lapidea vel calcarea; " ejus quidem formæ ut apparerent excorticantis se calculi " ramenta esse. Quamvis autem longo tempore ejus modi " materiem copiosè redderet, calculi tamen symptomata ideo " non mitigabantur, neque imminutus deprehendebatur cal- " culus. Ita quidem ut tandem post collectam magnam ra- " mentis hisce repletam pyxidem, puer sectione liberari a " magno calculo debuerit."

When the bladder suffers repeated irritation from stricture in the urethra, or from any obstruction near the prostrate gland, we find mucus discharged from it in greater or less quantity; and very often with this mucus a fine white powder resembling chalk. This powder is a solid substance, and nobody can doubt, but that it is secreted from the mucous glands.

Though mucus is so much disposed to assume a solid form, yet, when calculi are generated in contact with mucus and urine, it is not easy to prove that urine has absolutely no share in their production. Indeed, it may perhaps contribute some small share in many instances; it may yield something even to those formed out of the bladder, though evidently but little. In certain cases of calculi generated within the body, the argument against the concurrence of urine in their formation is yet stronger, because in some of these cases the calculi have no communication whatever with urine. For instance, when stones are

formed between the coats of the bladder or ureters, which are not uncommon; and in the very center of the prostrate gland, which are very common. The urine has but little access to many of those formed in sacs and herniæ of the bladder. I will now describe the most remarkable of these cases which I have seen or read of.

Stones are often found between the coats of the bladder or ureters, sometimes having a communication with the cavity of the bladder, at other times, so inclosed in their proper bags, that there is no communication whatever between them and the urine. It was formerly conjectured, that the calculi thus incysted, meeting with some impediment to their passage through that part of the ureters where they enter the bladder, had forced their way through the inner coat, and lodged between the coats of the bladder. Morgagni rightly observes, that, if this were the case, the stones so incysted would by the force of gravity sink to the lower part of the blad-

der. In justice to him I will transcribe his words on this subject: they strongly mark his philosophic candour and judgment, and evince, that some principle, which had not occurred to his predecessors, or himself, was wanting to explain these facts.

In treating of perfect cysts including calculi near the lower extremities of the ureters, he makes the following remarks. "But what Platner, and, before him, Littre "and Vater, have suggested, "that unless "stones pass freely, they probably make "themselves a new way; whilst the bladder "being occasionally contracted forcibly, "they are propelled within its coats to-"wards its neck; and that this is the rea-"son, why they are often found in places "remote from the mouths of the ure-"ters."—"This, I could very readily be-"lieve, concerning such cysts as were seen "by Littre, between which and the lower "extremity of the ureter he could trace "a communication, which once made, it is

" probable, would afterwards be kept open
" by the perpetual flow of urine into them.
" Having considered the above-cited pas-
" sage, I make no doubt, but that the words
" remote places from the lower mouths of
" the ureters," are to be understood as only
" downwards, agreeably to the impulse of
" the descending urine, and to the force of
" the bladder, contracting in that direc-
" tion. In what manner then, shall we
" be able to explain so many other obser-
" vations, which Platner mentions in the
" same passage, concerning stones of the
" urinary bladder included in membranes.
" Were they all either below, or at the ori-
" fices of the ureters? Was this also the situ-
" ation of others, besides those which are re-
" corded in the Sepulchretum? and parti-
" cularly in that case of Tulpius, (for Plat-
" ner has recited only one more of the many
" cases to be found in Tulpius) in which
" thirty-nine stones are described in the
" bladder, each of which was included in its
" proper receptacle, and so perfectly con-

" cealed, that the surgeon at first conceived
" there was no stone in the bladder. Add
" to this one more case, from Holtzapellius,
" which gives an account of thirty-two
" stones, included in their proper coverings,
" and contiguous to each other, so that, like
" bees in the cells of a honey-comb, these
" stones, each in its proper cyst, filled the
" whole cavity of the bladder, in such a
" manner, that only a small passage was
" left for the urine." Were all these then
" below the orifices of the ureters? Some-
" times indeed I have been inclined to con-
" jecture, as I have found biliary stones
" within the small glands of the gall-blad-
" der, that perhaps the orifices of the small
" glands of the urinary bladder, which ori-
" fices, as I have sometimes seen them open
" in the ureters, might possibly be open now
" and then also in the continuation of the
" bladder; that perhaps these orifices, might
" admit into the cavities of the glands the
" minutest granules of sand, which might
" in these cells increase, and become stones.

" But until an opportunity offers of dis-
" secting, and attentively examining a
" bladder which contains within its coats a
" stone, situated where it could not come
" from the ureters, I withhold my full assent
" to the above hypothesis. And, since I am
" assured, from my above-mentioned ob-
" servations, that the orifices of sacs are often
" much less than the sacs themselves, I will
" not altogether reject that other conjec-
" ture, but suppose it possible, that a stone
" might enter a sac when small, and that
" the opening to it might gradually con-
" tract, and almost, if not entirely, close up.
" But there are sometimes in one bladder
" many sacs, among which some are small,
" situated not only in the lower, but in the
" middle, and upper parts of the bladder.
" This may be understood from my ob-
" servations, and still better from the plates
" which the celebrated Heister has inserted
" in his Chirurgical Institutes, for which he
" deserves the greater credit, the more it had
" been to be wished that they should not be

" altogether neglected by any of those who " have written on lithotomy, since those sacs " have been very often mentioned."*

* " Quod autem Platnerus, Littrium, et Abr. Vaterum " secutus, addidit, ni calculi inde, excidant, " videri sibi " novam viam facere, dum contracta subinde valentius ve- " sica, intra hujus tunicas versus cervicem propelluntur: " et hanc causam esse, cur sæpe in locis, qui ab ureterum " osculis remotiores sunt, reperiantur;" illud quidem tunc " facilius crediderim, ubi ab uretere infimo viæ pateant ad " ea loca, ut ab Littrio conspectæ sunt, quas semel a cal- " culis apertas veri simillimum est, patulas deinde a sub- " sequente jugiter urina servari debere; remotiora autem " ab osculis ureterum loca, ab iis deorsum tantummodo, " verbis etiam quæ descripsi, spectatis, intelligenda esse, non " dubito, quo tum descendentis per ureteres lotii pondus " urget, tum contractio vesicæ compellit. Quanam igitur " ratione tot alias quas Platnerus ipse ibidem commemorat, " Observationes explicabimus vesicæ lapidum membrana " inclusorum? num omnes ad ureterum oscula, aut infra " hæc fuerunt? num sic alii quoque in aliis, præter illas, " Observationibus in Sepulchreto legendis? una Tulpii in " primis (neque enim, cum ibi plures ex Tulpio sint, om- " nes Platnerus, sed aliam quandam indicavit) qua 39 cal- " culi in vesica describuntur, quorum " latitabat unusquis- " que involutus proprio receptaculo, et quidem tam tecte, " ut circa initium crediderit chirurgus, nihil calculorum illic " detineri." Cum hac junge alteram Holtzappellii, cal-

Thus stood the doctrine concerning incysted calculi, under the hypothesis of

" culos proponentem 32, " omnes in propriis tunicis in-
" clusos, et invicem contiguos, ut haud aliter quam apes in
" suis cavernulis favum, sic isti calculi in suis quisque al-
" veolis, totam vesicæ cavitatem replerent, exiguo tantum
" meatu urinæ relicto." Num ergo hi omnes infra oscula
" ureterum condebantur? Et mihi quidem aliquando venit
" in mentem, ut quemadmodum intra felleæ vesicæ glan-
" dulas bilarios calculos inveni, ita suspicarer, num forte per
" glandularum vesicæ oscula, quæ ut in ureteribus pa-
" tentia nonnunquam deprehendi, sic etiam interdum in
" continuata vesica patere nihil prohibet, arenulæ minu-
" tissimæ in glandularum cava irrepere possint, ibique in
" calculos suis alveolis inhærentes augescere. Sed donec in
" vesicam incidere contingat quæ inter tunicas ibi con-
" clusum habeat calculum quo ex ureteribus prevenire non
" potuerit, eamque attentius examinare; malim interea a
" meo illo cogitato assensum cohibere: et quoniam ex meis
" supra indicatis observationibus didici, sacculorum orificia
" sæpe esse sacculis ipsis multo minora; conjecturæ quoque
" alteri locum aliquem dabo, ut puta si minore calculo in-
" gresso, orificium quacunque de causa magis arctaretur,
" et pene, aut prorsus occluderetur. Sunt autem sac-
" culi unam ad vesicam interdum plurimi, inter eosque
" etiam parvi, et non modo inferiores, et medias, sed et
" summas partes vesicæ tenent: quæ cum ex meis illis
" observationibus, tum evidentius ex duabus intelliges
" iconibus, quas, ut alias quoque dixi, Cel. Heisterus ad

their formation from urine. The best solution of these difficulties, which this judicious and learned physiologist could devise, was to refer the incysted calculi to the lacunæ of glands. What would he have said, had he known that the fluid contained in these very lacunæ is capable of generating calculi? It would not then be necessary for the granules to pass from the cavity of the bladder into orifices, which he acknowledges with his usual candour, were too small for him to see, nor for these orifices to admit urine enough to enlarge them to the size of a stone, and then to close up on that side where the stone, being most exposed to urine, would necessarily grow fastest, and consequently press most; which pressure would not only dilate mechanically, but in the living body would

" latinas addidit suas Chirurgicas Institutiones tanto lauda-
" bilius, quanto magis optandum fuerat, ne ab ullo eorum
" qui postquam de illis sacculis sæpius facta mentio est,
" de Lithotomia scripserunt, prorsus omitterentur." *Morgagni Epist. Anat. Medica XLII. Art.* 31.

also promote an absorption of the edges of those lacunæ. These difficulties vanish, and the whole doctrine of incysted calculi becomes perfectly clear, if we admit, that the membranes which form the cysts are capable of generating stones.

The stones in the center of the prostrate gland, of which an account will be given hereafter, involve the ancient doctrine in still greater difficulties. Common sense revolts at the supposition, that either the lacuna of a gland, or an opening from the ureter, could make way for several small stones into different parts of the firm and hard substance of the prostrate gland, and leave no visible trace of their passage.

Van Swieten recites the following case from Hasenohrl. " A man was often af-
" flicted with paroxysms of calculous ne-
" phritis for many years, and had many
" times happily escaped from them. Yet
" he rarely passed his water without dif-
" ficulty, and frequently a red sand was dis-
" charged with it. At last he is attacked

" with most excruciating pains in his loins
" and high fever; falls into convulsions, and
" expires. Besides other appearances in the
" dead body, a hard resisting substance was
" felt in the right ureter near the bladder,
" which being extricated by dissection,
" exhibited a stone of an irregular figure.
" The cavity of the bladder contained a
" little urine, and the sides of the bladder
" were found here and there incrusted with
" sand. This man had acquired a calculous
" diathesis: there was a stone in the right
" ureter, but so covered with membranes,
" that the urine contained in the bladder
" could not reach the stone. The urine
" deposited sand upon the bladder itself;
" hence he had often voided sand; yet a
" stone was never generated in the bladder,
" though its sides were incrusted."*

* " Homo nephritidis calculosæ paroxysmis sæpius ex-
" cruciabatur a pluribus annis, et multoties indè feliciter
" evaserat: raro tamen urinam sine difficultate emittebat;
" sæpiusque una cum lotio exibat sabulum rubrum; tan-
" dem atrocissimi lumborum dolores cum febre acutissimâ

In the above-cited passage from Van Swieten, the sides of the bladder were observed to be incrusted with sand. It is observable, that the adhesion of stones to the sides of the bladder is often so strong, that they even break sooner than quit their connection with it. How can such an adhesion between a stone and the bladder be formed? Either those portions of the bladder to which the stones adhere must cease to secrete mucus, during the deposition of such stones, or that mucus must harden into stone, before such a connection between

" accedunt, et convulsus moritur. Præter alia in cadavere " observata, in dextro uretere prope vesicam tangebatur ob- " staculum durum, quod, sectione enucleatum, exhibebat " calculum irregularis figuræ. Cavum vesicæ pauculum " urinæ continebat, et latera vesicæ arenulis hinc inde in- " crustata deprehendebantur. In hoc homine diathesis " calculosa aderat; calculus erat in uretere dextro; sed " sic tectus membranis ut lotium vesicâ contentum non " posset alluere calculum; urina vel in ipsâ vesicâ depo- " nebat sabulum, quod toties eminxerat; nec tamen inde " natus fuit in vesicâ calculus, sed latera ejus incrustaban- " tur." *Van Swieten Comment. vol.* v. *p.* 209.

the stone and the bladder can take place. A fluid secreted and interposed, would prevent any firm adhesions; as we find when solid bodies are retained in the mouth, or in contact with other moist surfaces. The disposition of the mucus, in that very case, to form calculi, is evinced by the appearance of the stone within the coats of the ureters.

The following case was communicated to me by Mr. Howard, of Argyle-street.

" Mr. M. aged 17, having had the stone as long as he could remember, was cut by the late Mr. Pott, October 17, 1774. The stone was extremely hard, of the colour of iron, and rugged, with a number of points arising from it. When weighed in the hand, it seemed as heavy as crude antimony, and not much unlike it; and when viewed in the sun, a prodigious number of small shining particles were perceivable on its surface. Its size was that of a small walnut. There was nothing uncommon or alarming in the early symptoms: he

wetted very plentifully from the time of the operation, and the wound looked well: but there was daily a discharge of a large quantity of discoloured mucus or matter from the bladder, and very little urine came by the penis for the first fortnight. In the afternoon of Nov. 6, that is, twenty days from the operation, I was sent for in a hurry, the patient having been alarmed by a considerable hemorrhage from the bladder and wound. The bleeding had ceased before I could get to him, which was at seven in the evening. He was in most excruciating pain. The wound was so clogged with coagula, that he now wetted but little. He had a strong desire to make water, but could not make a drop, and complained of great pain in the glans. He continued in pain till two in the morning, at which time, after feeling what he called a lump over the os pubis in the region of the bladder, a torrent of fluid came suddenly forth from the wound, partly urine, and partly blood: He became immediately easy, had

no return of the hemorrhage, and did well.

"In this case, either during the continuance of the mucus discharged before, or after the hemorrhage, I have forgotten which, certain sloughs, to each of which were firmly attached small distinct calculi, resembling in colour and appearance that which had been extracted, were separated from the bladder. These sloughs were ragged, but firm; and it struck me at the time, that they were separations from the internal coat of the bladder. These stones were of various sizes, from a large tare seed, to the smallest pin's head, and perfectly distinct the one from the other. They were firmly united posteriorly to the sloughs; anteriorly, they were clean, rough, and shining, and were apparently rudiments of the same kind of stony concretion as that taken from the bladder."

In this case, we have both incrustations and stone in the bladder.

Mr. Blicke favoured me with the fol-

lowing particulars, which greatly elucidate this subject.

A gentleman was cut for the stone by Mr. Sharpe; the stone was extracted, but the gentleman lived only five weeks after the operation. The bladder, ureters, and kidneys of this gentleman were lined universally with a membrane, containing all through, or over it, a substance resembling chalk. One kidney was enlarged, and contained much of a similar substance. The prostrate gland contained, within its very parenchyma, the same kind of matter.

The incrustation is here traced into the very substance of the prostrate gland.

If we can thus account for the appearance of calculi between the coats, and for their adhesion to the sides of the bladder, we shall find little difficulty in explaining the cause of sacs communicating with its cavity. Indurated mucus, lodged near the orifice of a mucous vessel opening into the bladder, would gradually increase, and, dis-

tending the duct in every direction, would produce this kind of sac, analogous to those which we daily see formed in the lacunæ of sebaceous glands. Or if a diseased portion of the bladder secrete viscid mucus, which adheres to it, and hardens, the sides of the bladder finding resistance in that part, and constantly suffering pain upon contraction, would gradually give way, and form a sac. Cystic herniæ, including stones, afford instances of this kind of sac. It is possible, that the weight of a stone upon the depending part of the bladder, may sometimes contribute in a small degree to produce a sac. It is not certain, that the urine has absolutely no share in the formation of stones thus included, as they may have a small communication with the cavity of the bladder. I do not therefore draw any inference from them, as to the origin of calculi in general, I mention them only to shew how easily we can account for the appearance of calculi in any way entangled with the coats of the bladder, supposing calculi

to be a production of the bladder. If, on the other hand, it be supposed a deposition from urine, it is not easy to explain the formation of sacs communicating with the bladder, and altogether impossible to account for perfectly distinct cysts, including calculi.

Sacs communicating with the bladder have been accounted for in this manner. That the stones when small are, by some means or other, insinuated between two or more muscular fibres of the bladder; and that these fibres contracting, the stone is confined, and a sac is formed round it.

It is possible that this may have happened; but we cannot admit it as a general cause of the fact in question, because it is not certainly true, and indeed is in some respects improbable. Supposing a small stone, or a piece of gravel, to be formed from urine, it has no fixed attachment to any part of the bladder; and the constant flow of urine, and moisture of the mucous membrane, would prevent any attachment,

while the stone is free to move into any part of the cavity. If by any accident a stone be constantly pressed against the same part of the bladder, that part may give way, and a bag may thus be formed; which happened in a case, which shall be mentioned hereafter, when a stone was generated upon a pin. I believe it is not true, that the muscular fibres of the bladder ever act in such an irregular manner as to form bags, without some disease, or fixed local stimulus, which a small stone in the open cavity of the bladder cannot occasion.

The formation of a sac is in one instance well accounted for by the pressure of the head of a pin against a part of the bladder.

" There was no urine in the bladder, " which was contracted, and of an irregular " figure; for at its superior right side it " was dilated into a square sac of a moderate " size, already becoming black. What this " was, and what it contained, was very " evident, as soon as the upper part of the " urethra, which we had not yet examined,

" and the bladder, were cut through from
" within. And in that part of the urethra, as
" far as the whole seminal caruncle, which
" was shrivelled, but furnished as usual with
" its sinus, we found no more disease than
" in the part of the urethra already exa-
" mined. But immediately above the ca-
" runcle, the whole inner surface, not only
" of the prostate, but of the bladder, was
" observed to be ulcerated, and covered
" with a kind of whitish eschar. Upon
" dissection, the coats of the bladder ap-
" peared to be thickened, and in some parts
" livid and black, in others white and schir-
" rous. So likewise was the sac above
" mentioned; for it not only communi-
" cated by an opening as large as itself
" with the bladder, but was formed of an
" elongation of all its coats. Within it
" was a calculus of the size of a moderate,
" or rather a small walnut, and somewhat
" also of the shape, smeared with a little
" moisture resembling the white of an egg;
" from the side of which, near one of its

" extremities, proceeded the pin, and pro-
" jected for the breadth of two fingers:
" the remainder of it, towards its head, was
" buried deeply, or at least very firmly,
" within the stone, for the space of another
" finger's breadth, if not more. But the
" part towards the point, which was very
" sharp, being perfectly straight, for the
" pin itself was rather a large one, and of
" considerable strength, extended so far
" obliquely downwards, without the orifice
" of the sac, that the point was fixed into
" the inferior and left side of the contracted
" bladder; whence it was extracted with-
" out any difficulty."*

* " Erat vesica sine urinâ, et in se contracta, abnormi
" autem figurâ. Nam ad summum dexterum latus ex-
" crescebat in quadratum quendam saccum mediocrem, jam
" nigrescentem. Hic quid esset, et quid contineret, apparuit
" omnibus, incisâ ab interiore facie primum supremâ, quæ
" inspicienda restabat urethræ parte, tum ipsâ vesicâ. Et in
" illâ quidem urethræ parte usque ad seminalem totam ca-
" runculam, quæ strigosa erat, suo tamen sinu secundum na-
" turam prædita, nihilo plus vitii deprehendimus, quam in
" dissectâ antea reliquâ urethrâ. Sed continuo supra carun-
" culam, non prostatæ modo, sed et vesicæ interior facies

In the 25th Article of the same Epistle is recorded a case of a young woman, described by Mariani, in which the head of a pin is incrusted with a pyriform stone. It was observed, before the death of the young woman, that the point of the pin stuck in the urethra.

" universa occurrit exulcerata, et subalbâ quadam quasi " escharâ obducta. Tunicæ autem vesicæ quod secando " fuerat animadversum, crassæ factæ erant, et in parte li- " vidæ et nigricantes, in parte albæ et quasi scirrosæ. Ne- " que aliter is saccus se habebat, de quo modo actum est, " quippe non solum orificio æque ac ipse amplo cum ve- " sicâ communicans, sed ex omnibus hujus productis tu- " nicis factus. Erat intra ipsum calculus nucis juglandis " mediocris vel potius parvæ magnitudine, et quadantenus " etiam formâ, humore albumen referente non multo obli- " tus: ex cujus latere extremo alteri propiore, acus illa exi- " bat, prominebatque ad digitos traversos duos: parte sui " reliquâ, quæ ad capitulum spectabat, intra calculum alte, " firmissimè certe conditâ, ut digitum transversum alterum " æquare et fortasse etiam superare posse videretur. Sed " pars illa altera quæ ad cuspidem eamque acutissimam per- " tinebat, rectissima, quippe ut in acu quæ ex firmioribus est, " neque ex tenuioribus, tantum extra sacci orificium deor- " sum ex obliquo se demittebat, ut in imum contractæ ve- " sicæ sinistrum latus acumen infigeret, unde nullo negotio " extractum est."—*Epist.* XLII. *Art.* 28.

"Upon opening the abdomen, matter "was found in the pelvis, and was supposed "to have been effused from the kidneys, "which were suppurated. In the space- "lated bladder was a pyriform stone, which "gradually lessened as it descended from "the head and superior part of the pin. "When it was withdrawn from the blad- "der, to which it adhered in a certain part, "it left small scales firmly attached to that "place."*

The lower part of the pin being least incrusted; the head, which pressed against the upper part of the bladder, being covered with the thickest part of the stone; and this stone adhering to the bladder with such force as to break, and leave scales sticking to the bladder, when an attempt was

* "Ventre aperto pus in hujus pelvi conspectum est, cre- "ditumque a renibus qui suppurati erant effusum. Ve- "sicæ sphacelo correptæ inerat calculus pyri formâ, nam "quo magis à capitulo et superiore acus parte descendebat, "eo magis se extenuabat. Cum è vesicâ ad quam aliquâ ex "parte adherebat, attolleretur, squamulas ad eum locum "agglutinatas reliquit."

made to remove it, are all proofs that the stone was in its formation intimately connected with that part of the bladder. Had the urine produced the stone, the pin would have been most incrusted below, where it was most constantly in contact with urine.

I was favoured by Mr. Blizzard with the history of a stone, which resembled this in many particulars; but happily differed in the event, as he extracted the stone, and saved the patient.

A young woman, troubled with suppression of urine, in consequence of stones in her bladder, attempted to remove the stones from the urethra, and make way for the urine, by introducing a black hair-pin head foremost into the urethra. The pin unfortunately slipped out of her fingers, and went into the bladder. Mr. Blizzard dilated the urethra, by continual pressure, to such a degree, that he could introduce his finger into the bladder, where he felt the pin, surrounded towards its upper part with a pyriform stone. This pin, which I

have seen, is not at all incrusted with stone at or near its point, which was fixed in the lower part of the bladder.

If calculous matter were precipitated from urine, all substances incrusted with stone in the bladder, would be incrusted in every part of their surface, but most abundantly in the depending part.

It may be asked, why the point, or lower part, was not incrusted from the same cause as the upper; that is, in consequence of its irritating the coats of the bladder. Indeed I know not, unless the mucus be washed off, and less disposed to harden, by a more constant communication with urine; or unless it be possible, that the pricking of the bladder by the point might produce a different discharge, an admixture of blood, or some other alteration.

Tulpius describes a case, in which it appeared to him, that a foreign body was incrusted with indurated or concreted pus.*

* Erat autem hic lapis, ut fragilis, sic accretus duntaxat ex pure indurato. *Tulpius Observat. Med. lib.* III. *c.* ix.

That irritation, applied to a part of the bladder, gives occasion to the production of calculi from that part, is sufficiently proved by these cases.

The growth of stones, in herniæ and in cysts of the bladder, and several circumstances in the above-mentioned incrustations upon foreign bodies, afford some degree of argument, that the lithopoietic power is greater in proportion as the communication with urine is less. A large secretion of urine has a tendency to prevent calculous concretions, and for this reason hard drinkers seldom experience this among their sufferings. In Haller's Disputationes ad Morborum Historiam et Curationem facientes, v. iii. p. 479. is contained a very extraordinary case of stones produced in the urinary bladder, and in the intestines. In this case, there was a suppression of urine; but though the catheter was introduced every third day, no water was discharged by it oftener than once in ten or eleven days, and even then only two or three

ounces of a green mucous fluid came away.

It sometimes happens, that the parenchymatous substance of the kidney is consumed, and that only a bag formed of its membranes remains. In these cases, it is probable that the secretion of urine gradually diminishes, and at last ceases altogether. When a gland is absorbed, most commonly the action of its secreting vessels have been previously diminished, or suspended; in which case, the quantity secreted is primarily lessened or annihilated; or, it may happen, that some neighbouring vessels have commenced an increased or diseased action, by which the adjacent gland is absorbed, and its secretion consequently ceases.

In the year 1782, Doctor Latham sent to me, then residing at Oxford, an account of a disease and dissection, from which the following description is extracted.

" The left kidney had nothing left of it but a mere membrane, which, being dis-

tended, at first appeared natural, but being cut open, was found completely filled with a substance in colour and appearance like plaster of Paris."

Whence came this substance? Does the natural mucus assume this form in the absence of urine? or was the membrane which contained, and probably secreted it, diseased? While urine continued to flow from the kidney, it is hardly possible that a substance of such a consistence could lodge in the pelvis of the kidney. Substances immersed in urine for any length of time, always acquire a darker colour. These are reasons for supposing the urine could not have any share in its composition; and what is more, as the distended pelvis was full of this matter, a part of it must have been generated after the kidney was totally absorbed, or at least in an evanescent state; so that the space it had occupied might be filled by this substance.

The stony incrustations upon foreign bodies within the bladder, differ from those

which usually form upon a solid body immersed in a fluid, in this respect, that the whole surface of a solid, immersed in a fluid, whose contents are crystallizing, is more or less incrusted; whereas the substances in the bladder are but partially incrusted. Morgagni conceived that this unequal crystallization was owing to the different degrees of smoothness of any foreign body in the bladder; but we find, that in this and in all other circumstances, crystals form upon the smoothest surfaces. The contents of the urine crystallize firmly upon glass.

The very surfaces of urinary calculi show a peculiar kind of crystallization, which proves that they are not formed in an uniform medium. Different parts of the same stone differ greatly, not only in external appearance, but in internal qualities.

Mr. Lane has proved, by experiments which deserve to be made public, that different parts of the same stone differ chemically from each other. It is not uncommon to find stones nearly divided into he-

mispheres of different colours. Mr. Abernethy found a stone in the bladder, of which about one half was immersed in mucus: the part thus immersed was somewhat more prominent than the rest of the stone. In Mr. Gunning's collection of calculi, are some very fine specimens of this appearance. A large portion of the sphere, in one of his calculi, rises nearly a tenth of an inch above the other part of its surface. The shell, or projecting part, is of a whiter colour than the rest, and of a more porous texture. The surface of the flattened hemisphere is of that red colour which substances, exposed for some time to urine, usually acquire.

I apprehend that the white part, which grew the fastest, and is most prominent, was immersed for some time before its extraction in mucus, of which it has the colour, and that the rest was covered by urine. The prominent parts of calculi in general are whiter than the rest: those parts which have been longer formed, and exposed to urine, acquire a red colour.

Calculi which are formed where urine has no access, are usually of a white colour.

The effects of irritation, applied to the whole surface of the bladder, or cavities contiguous to it, are specifically similar to those arising from partial stimuli. This happens, when foreign bodies introduced into the bladder are of such size and figure as to be moved to any part of the cavity; from spontaneous diseases of the membranes through which the urine passes, arising from internal causes; or from stimuli applied to the urethra, prostate gland, or other parts connected with the bladder.

Many foreign bodies have been taken from the bladder, uniformly incrusted with stone. I have at this time a large stone, surrounding a piece of congealed blood. I believe no foreign body was ever extracted from the bladder, which had remained long there, without having acquired a calculous incrustation. It is not therefore necessary to the formation of such incrustations, that the urine be of a particular quality; nor

do they depend only upon the urine. In that case they would not be so constantly produced, because the urine is not always disposed to incrust substances immersed in it. I kept five grains of an urinary calculus for several weeks in urine, which was changed daily; and, after drying the calculus, could discover no alteration in its weight. Yet circumstances are more favourable to crystallization in the open air, than in the living body. Indeed, the circumstances which favour crystallization, are rest and cold: neither of which can be easily obtained in a living body; and least of all in one afflicted with stone in the bladder. I am here speaking of fresh urine, as it is in the bladder: the case is altered by putrefaction. If urine, whose parts are held in perfect solution, be left to putrefy, a decomposition will take place, and incrustations will be formed on the vessels containing it, and on bodies immersed in it.

Thus it appears, even from considering the subject in this slight and general way, that

the constant incrustation of foreign bodies in the bladder, depends upon a particular state either of the urine, or of the mucus, induced by the presence of such foreign bodies. Therefore, when these bodies are removed, the persons who have suffered from them are usually cured, and cease to generate calculi. But, if the urine were disposed to precipitate its contents within the bladder, independently of such irritation, this would not be the case, neither would it come away clear. When there is a predisposition in the habit to form stones, we see them produced without the introduction of a foreign body, as often happens after a fit of the gout. The removal of a foreign body would not cure the stone, as it generally does, unless that foreign body acted as a cause of the disease, independently of any primary disposition in the parts affected ; or unless, when such bodies are removed by lithotomy, the operation itself, of making an incision through the prostate gland, and part of the bladder,

may induce some change in the state of those parts, and thus assist in the cure.

Of the stimuli applied to the whole surface of the bladder, the most common is that by stricture of the urethra: but this kind of stimulus does not often produce a large stone, though it very often gives occasion to the formation of a white powder, in appearance resembling chalk. A similar irritation sometimes gives occasion to solid concretions, as is evident from the following case.

A man's urethra was much bruised, and the sides of it grew together for the space of two or three inches: the urine was discharged through an opening *in perinæo*. Mr. Blizzard cut an artificial urethra, and kept it open by means of a bougie and catheter, till the sides of the wound united, and inclosed the instrument: thus an excretory duct was again made for the secreted fluids. During the cure, the catheter was kept in the bladder for some days, without being extracted; and upon being withdrawn

was incrusted in one part with a thick lamina of white stone. The urine voided by this man during the process, deposited mucus, which hardened upon the pot, and there left a crust of a similar colour. This man assured me, that his urine exhibited no such appearances before his urethra was injured.

It may be worth while to compare with these observations, the cases which are to be found in medical writers of incrustations on foreign bodies in other mucous parts. It must be acknowledged, that these occur less frequently than in the bladder: the reason of which, though very obvious, has not been often, if ever, assigned; viz. that no other cavity leading out of the body is so large as the bladder in proportion to its termination. Substances introduced into the mouth, intestines, nose, uterus, can with equal ease pass out again, and therefore are seldom retained; yet we meet with cases abundantly sufficient to prove, that when foreign bodies are retained in these parts, they become incrusted with stone. The for-

mation of what is called tartar upon teeth, which is strictly analogous to these incrustations, is universally observed; yet we seldom find any other body incrusted in the mouth, because foreign bodies are not often kept there for a sufficient length of time. A seed of an orange stuck under the tongue of a young woman, and after remaining there for some time, was found to be incrusted with a thick coat of white stone: it was extracted by Mr. Gunning, and is now in his collection of calculi. I have seen, in Doctor Baillie's Museum, an incrustation formed upon a pessary. In the forty-fourth observation of Ruysch's Century of Anatomico-Chirurgical Observations, we have a case of a large stone incrusting a piece of amber, which had remained for some years in the nose. He has given a print of this stone. He mentions in the same place, that he had seen the stone of a cherry, which had been said to have lodged in the nose, and which was covered over with a stony shell. It is unnecessary

to say any thing of incrustations upon foreign bodies in the intestinal canal, as they are to be found in many authors. Many observations on this subject are collected in Haller's Elements of Physiology, vol. vii. p. 175.

The connection between the gout and stone has been often observed by medical writers. An irritation in the bladder and kidneys often succeeds a fit of the gout, which irritation is sometimes followed, in the course of a few days, by an appearance of calculi. The old medical writers accounted for this, by supposing the gouty matter to be carried to the kidneys, and there to form concretions analogous to those in the joints. The principle, upon which this doctrine rests, is hypothetical. It has never been proved, that gouty concretions in joints are similar to those in the bladder: it is hardly possible that they should be similar; for even the stones in the bladder differ essentially from each other.

I know of no author who has entered so

particularly into this subject as De Haen. The following passages discover his sentiments on the formation of stones, and contain several facts which throw much light on the affinity between the gout and stone.

" Are we then to define a *calculous dia-*
" *thesis* to be a particular state or condition
" of the system, which disposes and enables
" the earthy matter, that is found in water,
" in urine, and in our common food, to re-
" tain its specific properties without any ma-
" terial reduction or alteration, so as to find
" its way into the circulation, where mixing
" with the blood, it is still subjected to no
" chemical change, either from the fluids or
" secretions it meets with in its course, or
" from the action of the vital powers, but
" passes on to the kidneys, where it is at
" length secreted along with the urine?

" Is the presence of gouty matter in
" the system in any degree conducive to
" the production of such a *calculous dia-*
" *thesis?*—Indeed, since a defect in the ul-
" timate process of digestion may be pro-

" ductive of gout, it seems not improba-
" ble, that some very minute particles of
" earthy matter escape the operation of the
" digestive powers; and as in the one
" case they are deposited in the small ar-
" teries of the joints, so in like manner in
" the other case, they may possibly be de-
" posited in the small arteries of the kid-
" neys, and hence become the cause of *cal-*
" *careous* urine. This opinion the cele-
" brated Adamus supports, in his disserta-
" tion published in the year 1740; where he
" takes occasion to relate the case of a man
" of seventy years of age, who, he observes,
" had always been extremely partial to
" every sort of food made either of sugar
" or milk, and who had been troubled with
" gout, affecting all his joints, for more
" than twenty years: but being wearied
" out with pain, he at length had recourse
" to a plaster of theriaca; by the use of
" which, for the last nine years, he derived
" considerable relief from his former pains.
" From that period he was taken danger-

" ously ill; and the disease afterwards as-
" suming the form of anomalous gout,
" shifted its situation at intervals to va-
" rious internal parts of the body: but for
" the space of five years, he suffered very
" excruciating pains in the region of the
" bladder, frequently recurring, with dif-
" ficulty of making water, and a variety of
" other symptons indicating stone in the
" bladder. For two years he passed in
" considerable quantity with his urine frag-
" ments of calculi, hollow, not unlike the
" shell of a nut; but for a year, during
" which time he had ceased to void these
" hollow pieces of calculi, he discharged
" along with his urine a quantity of mucus,
" which generally concreted into a hard
" chalky substance: and what is particularly
" deserving of remark, whenever the gout
" seized him, his water became perfectly
" free from mucus, and when the complaint
" left him, his urine began again to abound
" with it. The ingenious author afterwards
" goes into a detail of facts, quoted from va-

" rious writers, in confirmation of his theory
" concerning gouty matter, and likewise
" adduces examples, in order to shew that
" the *calcareous* matter of gout not only
" produces stony concretions in the uri-
" nary passages, but also in several other
" parts of the body.

" For my own part, I have additional
" reasons that induce me to subscribe to
" the probability of this doctrine. There
" was a gouty patient in the hospital for
" the space of fifteen months, who had
" excreted during a period of fifteen years,
" and still continued to excrete, calcareous
" matter from the vertebræ of the neck,
" from the feet, and from the joints of
" both hands. At first his urine was pale,
" and extremely furfuraceous; but during
" the last half year, it was not only fur-
" furaceous, but likewise constantly puru-
" lent; and for many days previous to
" his death, it was observed to be both
" limpid, and in very small quantity. On
" examining the body after death, there

" was nothing found, that could account for
" the origin of the purulent discharge: but
" the blood remaining in the body, which
" was incredibly small in quantity, had so
" polypous an appearance, that even the
" smallest drop scarcely escaped during the
" dissection; which circumstance, by the
" way, tends clearly to confirm what I had
" advanced in vol. i. chapter 11. on the ge-
" neration of pus. But, what favours our
" present argument most of all, both kid-
" neys, which in their cortical substance
" were thickened and enlarged, were per-
" fectly clogged and loaded with sand, in-
" somuch, that in whatever part they were
" cut into with the knife, a fresh surface of
" sand was constantly to be detected; for
" the *calcareous* matter of this gouty pa-
" tient, partly carried to the kidneys, would
" probably have soon exhibited *calcareous*
" urine, had it not obstructed the mouths
" of the ducts that secrete the urine, and
" hence nearly put a total stop to the uri-
" nary secretion, and also converted the

" whole cortical part of the kidneys into a " sandy kind of substance; yet the patient " never had what is termed the stone.

" Moreover, there is a case related by " Sigismundus Koenig to a society in Lon- " don, of a young girl, who, after suffering " violent pains in the joints, had at last " vomited up a number of calculi of a " pretty considerable size. The case of a " woman of fifty years of age is described " by Weismann, who, after labouring un- " der excessive gouty pains, at length dis- " charged, both by the rectum, and from " the vagina, a quantity of very small " stones. The celebrated Adamus like- " wise mentions, from Schneiderus, the " story of the famous Emperor Maximi- " lian II. who when living was severely af- " flicted with the gout, and after death was " discovered to have calculi in his heart."*

* " An præterea calculosam diathesim id demum ap- " pellemus, quod efficiat, ut terrestre id, quod in aqua, quod " in alimentis, quod in vino est, minus subigatur, ad san- " guinem vehatur, cum sanguine commisceatur, iterumque

It is sufficiently proved by these observations, that the attack of gout disposes

" humorum circuitu, ac vi vitæ non mutetur, et in renibus
" tandem cum urinâ secernatur?

" Nunquid etiam arthritica materies eidem producendæ
" apta? Utique, cum arthritidem ultimæ digestionis de-
" fectus efficiat, videntur minima quædam elementa ter-
" restria immutata manere; eaque ut ad juncturarum arte-
" riolas adplicantur, ita etiam ad eas renum adplicari posse,
" et urinas generare calcareas. Hujus mentis clarissimus
" Adamus est, in dissertatione anno 1740 edita, occasione
" sexagenarii hominis, qui perpetuo rerum aut saccharo,
" aut lacte, paratarum, impensus amator, arthritidi, quosvis
" occupanti artus, obnoxius ultra 20 annos vixerat; do-
" lorum vero pertæsus, eosdem novem abhinc annis the-
" riacæ emplastro sopiverat. Unde in periculosum mor-
" bum primo prolapsus, dein anomalam prorsus arthritidem
" in multis internis corporis partibus per vices expertus
" erat; a quinquennio autem acerbos vesicæ urinariæ do-
" lores crebro repetentes, Dysuriam, et varia alia calculi ve-
" sicæ symptomata. Biennium erat, quod ramenta calcu-
" losa, nucum putaminum instar concava, copiose emin-
" geret; annus autem, quod his ramentis absentibus mu-
" cum cum urina redderet, qui in cretaceam abire materiem
" soleret. Et quod præprimis notandum, podagræ accessu
" lotium eo muco carebat; podagræ recessu scatebat eodem.
" Confirmat deinde hanc suam de materie arthritica ideam
" autor eruditus variorum scriptorum testimoniis. Quin
" etiam exemplis demonstrat calcaream arthriticorum ma-

various parts to throw off something which turns to stone. It is also equally clear,

" teriem non modo ad vias urinarias, sed quoque ad quævis
" alia corporis loca concretionês producere lapidosas.
" Sane quæ mihi hanc sententiam probabilem reddant,
" plures habeo rationes. Arthriticum hominem nosoco-
" mium 15 mensium spatio aluit, qui ab annis quindecim
" tum colli vertebris, tum pedum manuumque ambarum ar-
" ticulis, calcaream materiem excreverat, et etiamnum ex-
" cernebat. Primo tempore urinam pallidam, et admodum
" furfuraceam emittere solebat; ultimo autem semianno,
" multo semper pure, una cum furfuribus, onustam; deni-
" que multis ante obitum diebus et limpidam, et paucis-
" simam. In cadavere nullus ullibi puris fomes: verum
" ipse sanguis, qui incredibiliter paucus in corpore supe-
" rerat, adeo polyposus fuit, ut vix guttula ejus inter se-
" candum prodierit; quod, ut obiter notem, clare ea con-
" firmat, quæ tom. i. cap. 11. de Puogenia scripseram.
" Quod autem maxime ad rem nostram; renes ambo in
" corticali suâ substantiâ crassi et ampli, omnino arenosi
" erant, ita ut quâcumque in parte nitido semper cultro
" secarentur, novam semper arenam proferrent. Quippe
" calcarea materies hujus podagrici partim ad renes delata,
" videbatur jam urinam calcaream productura fuisse, nisi
" eadem vasorum urinam secernentium ora obstruxisset,
" hincque tum urinæ secretionem fere impedivisset, tum
" ipsam corticalem renum substantiam reddidisset areno-
" sam. Calculosus ceterum nunquam fuit.
" Præterea relatus a Sigismundo Koenig ad societatem

that the parts which produce this, are the bladder, kidney, stomach, uterus, and other parts. At the same time, many of these parts are found to abound with mucus, and to secrete this in greatest quantity when under gouty irritation. The first described case is peculiarly illustrative of this doctrine. For two years stony fragments were voided with urine; then for a year these disappearing, mucus was discharged, which used to change into chalky matter. In the attack of gout, the urine was free from this mucus, with which it abounded at the decline of the fit. I conceive the stone in the joints to be formed in the same manner. A

" Anglicanam casus Juvenculæ, quæ post enormes artuum
" dolores demum in plurimorum, eorundemque majorum,
" calculorum vomitum inciderat: descripta Weismanno his-
" toria quinquagenariæ, quæ crudeles arthritidis dolores per-
" pessa, tandem tum intestino recto, tum ipsâ vulvâ, plu-
" rimos excreverat lapillos: notata denique ab ipso clar.
" Adamo enarratio Schneideri de invictissimo Imperatore
" Maximiliano II. qui podagrâ gravissimâ conflictari soli-
" tus, calculos in corde gessisse post mortem inveniebatur."
De Haen Rat. Medend. vol. ii. *p.* 75. *&c.*

mucous fluid is thrown out in consequence of gouty inflammation, the finer parts are absorbed, and the solid left. It is not uncommon to attribute the stone and gravel, which succeed fits of the gout, to the position of the body, and want of exercise. But happily for mankind, these causes are not sufficient to explain the phenomena: if they were, the stone and gravel would attend every disease, and even occupation, of long and constant confinement. Palsies, compound fractures, and even old age, could hardly be exempt from calculous complaints.

De Haen takes it for granted, that the sand which he found in the cortical substance of the kidney was deposited there from urine, and concludes, that the person so affected must have voided sand, had not the vessels secreting urine been obstructed with it. But if the urine were so loaded with calculous matter as to deposit sand at the instant that it was formed, for we know that urine passes almost instantaneously

through the kidney, we might reasonably have expected some deposition also in its further course, in the pelvis of the kidney, or in the bladder, where it rests much longer; which the author observes not to have happened. It is inconceivable how the urine should convey just sufficient calculous matter to obstruct all the uriniferous tubes of the kidney, and that none of it should at any time pass through them. I therefore conjecture, that the sand was not deposited in the cortical substance of the kidney from urine, but from the *tela cellulosa*, or congeries of vessels destined to connect and nourish the uriniferous tubes.

Of the glands which furnish mucus to the bladder, the principal is the prostate. How far the mucus secreted from this gland contributes to the stone in the bladder, cannot yet be determined; but it is certain that in this gland calculi are very often found. The two last people in whose bladders I have found a stone, have had stones also in the prostate gland. In the first of these

cases I had no particular object in view, and did not examine very minutely; but I think the stones in the prostate, which were numerous, and some of them large, in that instance, had no other communication with urine, than the prostate has in its sound state: and in the second case I can affirm, that there was no other communication between the bladder and the different parts of the prostate where these stones existed, than what must subsist by the excretory ducts of the prostate; as the gland and its ducts were perfectly sound.

A case has lately occurred, well known to some who were present at the reading of this lecture, in which there was a stone in the bladder of a whitish colour, and of a roughish surface; and in the prostate at least a hundred stones, of different dimensions, from the size of a pea to that of the smallest pin's head, of a darker colour than the former, and of a smooth surface: and in different parts of the neck of the bladder, many other stones, of the same

sizes, equally smooth as those last mentioned, and not quite of so dark a colour. A gentleman, who saw these stones taken out of the body, informed me, that he believed they had no connection with urine. —In this case there was a stricture in the urethra.—There are several cases of this kind in Morgagni, Epist. xlii. Art. 13. and in Epist. xlii. Art. 37.

The disposition of the prostate gland to form calculi may perhaps be one reason, though not the only one, why this disease is more common in men than in women.

We frequently see and read of calculi spontaneously formed in other parts, besides the urinary vessels; in the lungs, under the tongue, in the brain, in the stomach and intestines, in the joints, in the uterus. Those parts are generally productive of calculous concretions, which abound with mucus. In gouty and rheumatic affections, calculi are found in and near joints. I have seen almost every joint in the body partly incrusted with a substance resem-

bling powdered chalk, in a man who was said to have died of a rheumatic fever. I have observed a similar incrustation on a diseased portion of the urinary bladder, of which all the sound parts were free from incrustation. The uterus is often the seat of calculous concretions. Van Swieten, in the fifth volume of his Commentaries has collected many observations of calculi found in the uterus. In the appendix to Beverovicius his book on the calculus, p. 237, we have a well-authenticated history from Thuanus, of a woman, whose uterus was to the touch like shell, and resisted the knife like gypsum. She had died in the 28th year of gestation; and the surface of the fœtus, which had been so long retained, had acquired almost the hardness of stone. Mr. Rawlins, of Oxford, gave me a placenta, in the membranes of which was intermixed a considerable quantity of a hard substance. To the case already mentioned of stones in the bladder and intestines, we may add one from the Philosophical Transactions,

No. 250. p. 95. of stones in the stomach and bladder of the same person; parts which resemble each other only in being lubricated with mucus. In the Physical and Literary Essays of Edinburgh, vol. ii. Art. 26. the late Doctor Monro has related six cases of calculi, some of which were discharged from the intestines, and others found in them after death.

I have now enumerated many circumstances of calculous concretions, in which we may distinctly trace the proper effect of each fluid. In doing this, I have freely selected from authors of credit such histories as suited my purpose. In discussing an opinion of mine, the facts recorded by other writers have at least as much title to belief as those of my own observation. The principal conclusions which follow from the facts adduced are these:—That the stone is always much exposed to mucus in the bladder, p. 11 and 44: That mucus readily forms stone out of the body, p. 7, 8, 9, 10: That it forms crystals, which resemble

stones generated in the bladder, p. 8 and 9: That a stone grows faster in mucus than in urine, p. 9: That stones are found within the coats of the bladder, and in the prostate gland, where urine has no access, from p. 16 to p. 25: That of stones in the bladder, those parts, which are most in contact with mucus, and have least communication with urine, grow most rapidly, from p. 33 to p. 42: That the appearance of the most prominent, and last formed parts of stones, often resembles in colour indurated mucus, p. 43 and 44: That irritation excited in the bladder causes stones to be generated there, from p. 45 to p. 49: That as incrustations are formed upon foreign bodies in the bladder, so they are also in the mucous glands, and membranes in other parts, p. 64, 65, 66.

If the candid reader will give himself the trouble to compare any of these conclusions with the passages referred to, I flatter myself he will find them to be fairly and fully proved.

For my own part, I should be very sorry to carry these deductions a single iota beyond truth, or beyond the testimony of well authenticated facts. I do not presume to infer from any observations which have been made, that the urine may not often contribute something to the composition of the stone: I only contend, that it is not the principal source of the stone in most cases, and in some, that it does not assist at all in its formation. I conceive that the proximate cause of the disease, or stone, does not exist in the uriniferous vessels of the kidney, or in the fluid secreted from them, but in the coats and glands of the several cavities through which the urine passes.

PART II.

Deductions from some of the Symptoms and Remedies of the STONE.

THOUGH many of the symptoms of a stone are undoubtedly produced by the pressure of a hard body against the urinary vessels, and though it is demonstrable, that such irritation may be excited by this, independently of any other cause, as to put an end to a man's life in a very short time, yet in the course of this complicated disorder various circumstances occur, which cannot be referred to this principle, and of which no adequate explanation can be given, without supposing the parts contiguous to the stone to be in a distempered state.

Of the diseased state of the mucous membranes, in those who have been afflicted with stone, we have sufficient proofs in the dissections related in the former part of this work. Several cases have been communicated to the public by Doctor Cheston, in which stones in the urinary bladder were accompanied with disease of the kidney, and *vice versâ*. It were no difficult task to fill volumes with instances from different authors of diseases of the urinary organs accompanied with calculi: but such instances do not decidedly prove any thing in the present inquiry; as it may be urged that they are the effect, and not the cause, of the stone. Concerning the primary diseases of these parts, we cannot have the same positive evidence from dissection. When we open a bladder diseased in any way, we can never say, that a stone would have been formed, had the sufferer lived some time longer; nor can we ever prognosticate in the living body, that a stone will be found in the bladder at some future pe-

riod, even though the predisposing circumstances exist. Perhaps the cases related in the former part of this work, concerning the formation of calculi in cysts of the bladder, on foreign bodies, and in consequence of irritation or stricture in the urethra, are the strongest proofs of the distempered state of those parts, prior to the generation of the stone, which the subject admits of.

These diseases, whether the cause or effect of the stone, certainly do not deserve to be altogether overlooked (which I believe they have been) either in theory or practice.

I have therefore selected the following pathological observations, many of which elucidate further the opinion above delivered concerning the diseased state of the mucous membranes in calculous cases, and shew the connection of such disease with the symptoms and remedies of the stone.

Both men and women suffer very acute pain from gravel or sand. The granules

of sand, which are supposed to excite this pain, are often so small, that their figure cannot be distinguished by the naked eye, but they are confounded with the mucus deposited in the urine, unless discovered by the touch. Does this pain arise from the pressure of the particles of sand against the bladder? Is it possible that such minute particles should make so painful an impression upon the sides of the bladder, defended with mucus? I know a person who at this time discharges dark-coloured sand with his urine, but feels no pain either in the bladder or urethra, yet he has pain near the seat of the kidneys, where I suppose this sand is generated. May we not conclude, that the pain arises from the vessels, which are diseased and generate sand, and not from the mechanical action of it as an extraneous body?

The urine of people afflicted with stone or gravel is generally pale and clear, when not tinged with blood. Such urine is supposed to be least impregnated with saline,

earthy, or mucous matter; and therefore I apprehend least disposed to deposite its contents, and to incrust substances immersed in it. I do not deny that incrustations are formed in the urine of such people; but, from the appearance of the urine, it is probable that such incrustations are produced from the mucus, rather than from the urine itself. The urine in such cases is always mixed with mucus, which is distinct from the urine, and evidently was not secreted with it, but comes from the membranes of the excretory ducts.

The ages most subject to stone in the bladder have appeared to me, to be under puberty, and towards the decline of life. I believe this observation has few exceptions in men, but it does not apply to women. Female children sometimes discharge gravel, though they are not often afflicted with stone; but young women are, not unfrequently. With respect to men, does the increased action of the seminal vessels in the intermediate space, contribute to render

that period more exempt from this concretion?

The children, whom I have seen in this disorder, have generally had marks of a scrofulous habit. Old people afflicted in this way, have often very good health in every other respect. I recollect some instances of the stone in men, who are subject to cutaneous diseases of the herpetic kind, but not sufficient to warrant any general conclusion. I can obtain no information from books, on this part of the subject: Excepting some remarks on the obvious connection between the gout and stone, I am unacquainted with any practical observations that have been made on the constitution or habit disposed to calculous concretions, or on the diseases which accompany them.

The cure of this disease implies two intentions; one to remove an offending substance from the bladder, the other to restore the parts to a healthy state, by which a return of the disorder may be prevented. In many cases, the removal of a stone is

only a temporary relief, and stones are regenerated independently of any irritation from extraneous bodies. Numberless stones are sometimes found in the same bladder. In vain we look for nuclei, or peculiar centers, in many calculi; and when we do not discover them, the formation of calculi depends solely on a disease of the urinary organs: consequently, the removal of a spontaneously formed stone, without altering this state of the parts, would be only a palliative, and temporary remedy, just as much so as simple tapping in an incysted dropsy.

It often happens, that a stone passes through the urethra without any artificial help: but we cannot pronounce the person, who has parted with it, well of the disorder, though he may be easy for the present; because we often see many small calculi discharged from time to time by the same person, the cause remaining, and producing the same effects.

When calculi are the consequence of an

acute disease, as of a fit of the gout, the discharge of them approaches nearer to a cure, as the disposition to generate them in this instance is only temporary. If by any accident a calculus so formed should happen to be retained in the kidneys or bladder, till it is too large to pass through the excretory ducts, it keeps up irritation, and by so doing confirms the disease. The great Sydenham, to whom mankind is so much indebted, experienced this affliction.

The removal of a stone by the operation of lithotomy, often proves an effectual and permanent cure. It would not be easy to account for this, if the origin of the stone be referred to the kidneys; and if it be referred to the general state of the habit, such an effect would be absolutely unintelligible. But if the bladder, with the glands and membranes contiguous to it, be the seat of this disease, the change induced in these parts by lithotomy, will be found sufficient to account for the cure: For in this operation, the neck of the bladder, the

prostate gland, and the lower part of the urethra, are divided; the course of the urine is changed; the stone is extracted; and a large communication made with the open air: thus a long-continued irritation is removed, and a new stimulus applied to these parts. The effects of this are not more evident in the stone, than in other diseases of the urinary bladder.

I have often heard, that the late Mr. Cheselden, thinking there was a stone in the bladder, performed the operation of lithotomy upon a boy, in whom no stone could be found; yet the boy was relieved of some complaints, which he had felt in the bladder.

Doctor Carmichael Smyth communicated to me the following observation.

" Mr. Smyth, surgeon, of Perth, the cotemporary of Cheselden, who was the first, and for many years the only lithotomist in Scotland, told his grandson, Doctor Carmichael Smyth, that he once cut a boy for the stone, who had been for years afflicted

with the symptoms of the stone, and who upon examination with the catheter appeared to have one in his bladder; but when the operation was performed, no stone could be found. The boy however recovered extremely well, and was entirely relieved of his former symptoms."

A boy was cut by Mr. Blizzard, and relieved of several calculi. A small fragment happened to remain in the bladder, which made its way out in a few days after the operation. This fragment exactly fitted a dent in the stones which had been extracted, and undoubtedly lay in contact with them in the bladder; but in consequence of remaining in the bladder after the operation, it had acquired a coat much paler than those first extracted. I have seen a boy produce stones, a short time after undergoing lithotomy, very unlike that which was extracted from him.

These cases shew, that these parts are greatly altered by this operation, and that its effects are not confined to the removal of

the stone. In the two first cases, a disease of the bladder was cured by the operation; and in the two following, a new kind of calculous matter was secreted in consequence of it. We know, that in very many instances, the formation of calculi ceases after lithotomy.

These cases greatly illustrate each other, and explain the extensive influence of the operation. The change produced in the secretion of calculous matter, or the stop put to the production of it in some instances, and in others, the cure of a different disease of the bladder, are in some measure very similar effects: for the cure of the stone consists only in a certain change of the state of the bladder, so that the fluid secreted by it is less disposed to assume a solid form.

Thus the operation of lithotomy not only removes the stone or stones, that are generated, but may prevent the generation of more; otherwise it would be only a temporary remedy in those cases, where there

is a predisposition in the habit to produce stone. If that disposition remained, whether in the urine or mucus, the disease would inevitably be renewed; gravel or sand would be produced, and, unless fortunately discharged, would gradually increase. The presence of a large foreign body is not necessary to crystallization in the first instance, as is evident from the appearance of sand, which, once formed, must be considered as a foreign body, and may become the nucleus of a stone.

Had the production of a stone been considered as depending upon a disease of the membranes lining the cavities, which receive and transmit urine, our remedies would have been directed to the cure of such disease, and every application, which could affect those parts, would have been attentively tried: but the very reverse has happened; and the influence of pathological opinion upon practice, was never more strikingly exemplified, than on this occasion. The few remedies, which accident

has discovered for the relief of calculous complaints upon this principle, have been received with distrust, and rejected almost without a trial: therefore we have yet to learn, what may be done for this excruciating disorder in this way. If any remedy, or plan of treatment, could be discovered, by which the lithopoietic state of the membranes lining the urinary organs could be corrected, such a plan would not be merely palliative, it would in some measure promote the operation of solvents, and in many cases the urine itself would assist in the solution of the stone. There are many people afflicted with calculi, to whom the usual solvents afford no relief; and many who dare not, or who ought not, to submit to the operation. To give ease, or to stop the progress of disease in such circumstances, would be no small improvement of our art.

The medicines in common use for the relief of pain in calculous complaints, are such as are usually employed in painful affections of the mucous membranes in general.

When oily medicines with manna, decoction of leeks, and other mucilaginous fluids, are exhibited in the stone or gravel, I believe they are considered only as palliative remedies; but in cases of gravel, these remedies are not merely palliative, they often actually cure the disorder.

Many substances are observed to affect the urinary bladder, when it contains a stone, in a very extraordinary manner. Alkaline salts and lime-water afford ease long before solution of the stone can take place. I have known a person with a stone in his bladder much relieved of pain by taking lime-water only two or three days. It might be supposed, that these substances do good by softening the surface of the stone, but dissection sometimes proves the contrary: moreover, their operation on the bladder itself in this complaint is illustrated and confirmed by their having an equally good effect in other diseases of the bladder.* This circumstance tends also to

* Falconer's Treatise on Mephitic Alkaline Water.

invalidate the opinion of those, who suppose, that the urine is the instrument of pain in calculous cases, and that alkaline substances operate by correcting this vitiated quality of the urine. The urine is undoubtedly the chief vehicle in which these substances are applied to the membranes in question; but, that it is merely a vehicle, and that this singular effect is owing to the state of the bladder, is further evinced by the operation of substances, which have a contrary effect, and which would not affect a healthy bladder in the same manner. For instance, the person above alluded to, who was so soon relieved by lime-water, was always affected with pain after taking a glass of port wine. Every medical reader will recollect circumstances of this kind, which will convince him of the peculiar sensibility of the urinary organs, when they are the seat of the stone.

The remedies, which have been more particularly and attentively tried in the stone,

are the fixed alkalis, and lime. These remedies are deservedly celebrated in this disorder, and their operation on the stone within the bladder agrees with experiments made out of the body. But all calculi have not the same affinities; and some of them do not dissolve in alkaline menstrua. Doctor Dawson has proved this by a sufficient number of experiments, of which he has given a detail in the Transactions of the College. The use therefore of these substances, as solvents, is confined to particular kinds of calculi; and their effect, as medicines, must depend upon a proper application of them. Besides, in this, as in every other disease, the difficulty of cure must increase in a certain ratio of its extent and duration. A large stone will evidently be longer in dissolving than a small one; and a very large stone cannot be expected to dissolve in the living body: therefore the attempt should be made in the early stages of the disease. A stone, we know, is never a sudden production, and is generally discoverable before it has arrived

at such a size as to render solution very tedious or difficult.

If we consult authors on the effects of alkaline substances and lime-water in this disease, we shall find, that they sometimes afford relief to the painful symptoms of the stone, without effecting a solution of it; that sometimes they radically cure the disorder, by dissolving the stone, and removing the disposition to generate stone; and that at other times they are attended with no beneficial effects.

A few observations on this subject will not perhaps be unacceptable in this place, nor foreign to our present purpose.

" A man afflicted with a stone in his blad-
" der took Mrs. Stephens's remedy (lime
" and soap), in a liquid form, for six
" months, with the best success: he was
" free from all pain; he walked, he rode
" in a carriage, and on horseback; he bore
" any exercise and fatigue without any in-
" convenience. This relief of his sufferings
" lasted for twelve months; he then be-

" gan to feel a heat in his bladder, with " strangury, and frequent stimulus to " make water. By bleeding, and anti- " phlogistic remedies, these complaints " abated for some months: after this they " returned more frequently. Tired out " with these sufferings, he resolutely sub- " mitted to lithotomy: a stone was ex- " tracted from his bladder, ten drachms and " a scruple in weight, of an ochrey red co- " lour, hard, and of a dense texture. There " was no mark of the lithontriptics having " acted upon his calculus; but under the " use of those remedies the urine had al- " ways deposited abundance of a fine white " sediment. After he desisted from the use " of them, he discharged with his urine a " very fine sand, somewhat of a reddish co- " lour, resembling the stone which was af- " terwards extracted. He recovered fa- " vourably from lithotomy, and from that " time enjoyed most perfect health.

" Another calculous person took the " same remedies for three years; at first

" daily, afterwards at intervals, whenever " he felt the least pain, and always with " relief. He however observed no diminu- " tion of his health from the long use of " these medicines; nay he even grew fat- " ter."*

* " Calculo vesicæ laborans homo sumserat hæc re- " media, in forma liquida, per sex menses; et quidem " optimo successu: ab omni enim dolore immunis erat, " ambulabat, equitabat, curru vehebatur, quævis exer- " citia et defatigationes sustinebat, absque ullo incom- " modo: levamen illud malorum per integrum annum per- " stitit. Incepit dein ardoris sensum in vesica percipere, " una cum stranguriâ, et frequenti stimulo ad reddendam " urinam. Venæ sectione, remediorumque refrigerantium " usu, sedabantur hæc mala per duos tresve menses; postea " redibant frequentius. Horum malorum pertæsus æger " animose subivit lithotomiam; eductus fuit ex vesicâ cal- " culus, decem drachmas et scrupulum pendens, densæ fa- " bricæ, coloris rubiginosi, et durus. Nullum signum do- " cebat, lithontriptica in calculum egisse. Sub usu horum " remediorum urina copiam sedimenti albi admodum te- " nuis deposuerat semper. Postquam cessaverat illis uti, " cum urinâ prodibat sabulum admodum tenue, subrubel- " lum, similis coloris, ac erat ipse calculus sectione postea " eductus. Cæterum, post lithotomium optime convaluit, " integerrimâ sanitate fruens.

" Alter calculosus eadem remedia sumsit per integrum

The Right Honourable Horace Lord Walpole was relieved by soap and lime-water from very severe calculous pains, and passed thirteen years of his life with hardly any, even the slightest return of them. He now and then felt some irritation in making water; a symptom too inconsiderable to require any other medicine than a small quantity of lime-water. When he died, his prostate gland was large and distempered: his bladder thickened, but otherwise sound. Three calculi were found; two in the bladder, and one, as Doctor Pringle describes it, sticking in the passage in that part, which is surrounded by the prostate gland. This stone was lost. The two stones in the bladder were very smooth: their polish and colour he compares to a boy's marble. One of them weighed twenty-

" triennium; in initio quotidie; dein per intervalla, simul-
" ac vel minimum sentiret dolorem; et semper cum leva-
" mine: nullam autem sanitatis imminutionem a tam
" longo usu observavit; imo obesior factus est."—*Van Swieten Comment. vol.* v. *p.* 324.

two grains, the other twenty-one grains.—Whytt's Works, quarto edition, p. 441, and other parts.

These cases are sufficient to prove, that soap and lime-water, and even lime-water alone, are capable of relieving calculous pains, while the stone is still in the bladder.

These observations further prove, that lime-water reaches the bladder in a very active state; and consequently, that part of it at least is not rendered mild in its passage to the kidneys: if it were rendered mild, it would become mere common chalk, would be precipitated in great measure from the water, or if it should reach the bladder in that state, it would have no effect upon the urine, and would exert no solvent power. That this medicine does reach the bladder in a very active state, is evident from the following experiments, which, I am well informed, were instituted by Doctor Heberden. They are related among Doctor Whytt's Cases, p. 446, 447.

" The Reverend Doctor Richard Newcomb, now Lord Bishop of Llandaffe, while drinking two English quarts of lime-water daily, for the cure of the stone in his bladder, poured his urine every morning and evening upon a piece of human calculus, weighing 31 grains; by which, in the space of four months, it was reduced to three pieces, weighing in all only six grains. Upon one of these pieces, weighing 2,31 grains, he caused to be daily poured, for two months, the fresh urine of a person who drank no lime-water; at the end of which time, the piece of calculus was found to weigh 2,56 grains, having increased in weight a quarter of a grain. This same piece being afterwards steeped in the Bishop's urine (who continued to drink lime-water, as above) from June 24 to July 9, was in these few days quite crumbled into powder.

" Since this experiment shews, beyond dispute, that lime-water, unassisted by

soap, can communicate to the urine a power of dissolving the stone out of the body, it can scarcely be doubted, that it must have the like effect on it when lodged in the bladder. And that the dissolution of the stone in the bladder has been completed by soap alone, appeared evidently in the case of the Reverend Mr. Matthew Simson, minister of Pancaitland, near Edinburgh; an account of which will soon be made public by Doctor Austin, who opened his body after death. Mr. Simson had, from 1730, been afflicted in a less or greater degree with the symptoms of a stone in the bladder, and in November, 1735, was sounded by Doctor Drummond, of Perth, and Mr. Balderston, surgeon, in Edinburgh; by whom a stone was not only plainly felt, but also by the patient himself. In February, 1737, he began to take soap; and after 1743, never had any gravelish symptoms. He died in May, 1756, and when his bladder was looked into, there was neither stone nor gravel found in it."

Doctor Home, in his Clinical Experiments, p. 450. *et seq.* has described some experiments on the urine of people who were taking soap-lees; from which it appears, that the soap-lees passed through the body without having lost their causticity; and that the urine impregnated with them possessed in a high degree the property of dissolving the human calculus out of the body.

Lime-water acts upon the same kind of calculi as the alkalis, and therefore these medicines will in general afford relief as solvents in the same cases, and may assist each other, as the solvent principle may be introduced into the habit in greater quantity, when they are administered jointly, than when either of them is exhibited separately.

The operation of lime-water upon the stone in the bladder, shews that substances which have a strong affinity to fixed air, may yet reach the bladder without being saturated with it: therefore alkalis may

reach the bladder in a state approaching to causticity. This is confirmed by the experiments of Doctor Home. It is possible, that the alkalis and lime-water may be combined with some oily or mucilaginous substances, in the form of soap, and by this means be defended from the action of fixed air.

It is proved by the experiments of Mr. Lane, that the solvent power of alkaline substances is diminished by combination with fixed air. He found, that the stone dissolved in the caustic alkali, was in some measure actually precipitated by the addition of the mild alkali. Consequently the mephitic alkaline water, which is a solution of alkali saturated with fixed air, is a weaker solvent than caustic alkalis. But in medicine, this question becomes complicated; and it is possible that there may be cases, in which the mephitic alkaline water may be preferable, as a remedy, to the caustic alkalis and lime-water. I was lately acquainted with a gentleman, who lost his

appetite, and was reduced to a low and languid state, while he took lime-water and soap-lees; but upon taking the mephitic alkaline water, his appetite, spirits, and strength returned. In this mild state, a much greater quantity of the alkali could be taken, and thus its want of power might be in some measure compensated: but it has not yet been proved by actual experiment, that the mephitic alkaline water has ever dissolved a stone in the bladder.

The gentleman, of whom I am speaking, was greatly relieved of his pains during the use of this water, and his urine, which had before incrusted substances immersed in it, no longer possessed that property. In the course of nine months, he took forty gallons of the mephitic alkaline water, made according to the directions of Doctor Falconer, to whom we are much indebted for the introduction of this medicine into general use. When he began this medicine, he could bear no exercise without great pain, and confined himself entirely to his house.

After he had used it for some time, he could walk with tolerable ease; yet, in getting into bed, and stooping down, he felt pricking pains through the penis: he was also still troubled with painful erections. From these symptoms, he was sensible that the stone was undissolved; and the more so, because his urine had been very pale and clear from the beginning of this course of medicine. He took it as an anodyne during the whole winter of 1780, 1781, being resolved to undergo lithotomy in the spring. When the operation was performed, a hard mulberry stone, of the size of a moderate chesnut, was extracted from him. This stone was of a very light colour. It was rough and porous within; the outward lamina, for about a tenth of an inch, was more dense and compact; and the surface was hard, with some shining points.

Twenty grains of this stone, immersed in two ounces of lime-water, for thirty-six hours, were not diminished in weight, or altered in appearance. A portion of the

dense superficial part, weighing five grains, being kept twenty-four hours in a drachm of aqua kali puri, diluted with half a pint of distilled water, still preserved its original weight. Hence it appears, that this calculus resists the action of the caustic alkali and of lime-water.

It is probable, that the dense cortical part of this stone grew during the use of the mephitic alkaline water, and that the surface of the stone was rendered somewhat smoother by this addition. If so, the alkaline medicines altered the mode of crystallization, though they did not stop its progress; but the stone continued still as unequal and hard in its surface as many stones which I have known to be attended with very severe symptoms. Consequently, the relief which took place during the use of this medicine cannot be altogether ascribed to the alteration in the state of the stone, even if we judge from its appearance at the end of the course: but the relief was felt within a very few days after the

first taking of the alkaline medicines, when we can hardly suppose, that any alteration whatever of the stone could have been produced. I apprehend therefore, that the mephitic alkaline water relieved the symptoms of the stone in this case, principally by inducing some change in the bladder itself.

PART III.

Experiments and Observations on the Component Parts of the STONE: *And a chemical Comparison of the* STONE *with* URINE *and* MUCUS.

WHEN the experiments, of which I now propose to give an account, were begun, I had adopted the opinion of Mr. Scheele, concerning the analysis of the stone. This truly sagacious experimenter discovered, that the calculi which he examined, when exposed to heat, yielded a particular sublimate, equal in quantity to nearly half their weight. He found that this sublimate was soluble in caustic alkali; he also observed, that his calculi were soluble in caustic alkali, particularly in the mineral. Although I had perceived in many in-

stances, that alkalis, caustic or mild, and lime-water, were sometimes ineffectual in such complaints, and that, in other cases, they gave relief, yet I had not doubted the doctrine of Scheele, supported by Bergman, and lately by Mr. Higgins.

I conceived therefore, that the particular object which I had in view, concerning the source of the stone, would at once be determined by ascertaining whether mucus or urine abounded most with the sublimate of Scheele. With this intention, I examined the residue left after evaporating urine; the residue after evaporating blood; the incrustation upon walls where people make water; and the incrustation also upon teeth: I exposed all these to a red heat for many hours, and attended carefully to their several products, but found, that none of these yielded the sublimate of Scheele in any sensible quantity. Not having just at that time sufficient mucus from the bladder of a calculous person to make the experiment upon, I dried the mucus expectorated by

a consumptive person, and also some mucus from a person's bladder not affected with stone, and exposed them to a red heat, but observed no sublimate to be produced from them. I was then supplied with mucus from a man who frequently voided small stones: I separated this from the filtered urine, with an intention of examining each of these apart; but previously to the examination, I tried to obtain the sublimate from the calculi of this man, and was surprised to discover, that these calculi, though urged with a strong heat long continued, gave no trace of the sublimate. I immediately tried another calculus, which did not dissolve in caustic alkali, with the same event.

Hence the doctrine of the universal presence of this sublimate in urinary calculi, which has been generally adopted for some years, appears to be ill founded. It is to be regretted on this occasion, that the difficulty of ascertaining the origin of the stone in general, upon chemical principles, is greatly increased by this circumstance:

for as they are found to differ so much in their composition, they may differ also in their formation ; and hence we can draw no general inferences concerning them.

It is not probable that substances so unlike each other are produced from the same glands, but that some arise from one part, and some from another ; or that some new combination from the secreted fluids of several glands takes place in the formation of the stone.

If all calculi had contained the same sublimate, and if that sublimate had not been found in urine, we might justly suspect, that that part at least of calculi in general, had some other origin: but, as this sublimate is found only in certain calculi, we cannot make the inference general, though we may with reason extend it to all those which do contain it. With regard to these therefore, since we find nothing in urine analogous to nearly one-half of their composition, we may presume, that these calculi at least, are not formed from that fluid.

Thus it appears to me at present from the analysis of urine in general: but before this question can be fully determined, both the urine and mucus of some person afflicted with a stone containing this sublimate must be examined.

Inquiring into the difference of calculi, which did, and which did not contain this sublimate, I was led into some observations on the nature of the sublimate itself, and into some distinctions of calculi, which seemed to deserve attention. The appearances, in all the experiments, were noted down as they occurred, partly by Mr. Abernethy, on whose attention and accuracy I could fully depend, and partly by myself.

We introduced into an earthen retort 320 grains of powdered calculus, being part of two calculi, both compact, and of a light brown colour. Soon after the application of heat, a light brown liquor arose, which tinged the vegetable blues green. Shortly after, crystals of volatile alkali were formed on the extremity of the neck of the retort.

As we were examining these, we perceived a smell, which resembled the prussic acid: we immediately put into the neck of the retort a piece of paper, dipped in an alkaline liquor, and in a short time found that this paper, immersed in a solution of iron, produced a fine blue precipitate. After the prussic acid had been formed, for a considerable time, we observed a dark brown fetid liquor, which, with the prussic acid, continued to come over until the end of the operation. These were examined repeatedly, with the same appearances; and a strong heat was kept up till nothing more was produced. After the operation, we collected ninety grains of sublimate, and four grains of distilled liquor; and there remained in the retort forty grains of charry matter in fine powder.

In another experiment, the residue from 320 grains was thirteen grains. In this experiment, attending to the aeriform products, we observed, first, fixed air, then inflammable air mixed with fixed air;

and, when there was a red heat, volatile alkali.

In order to ascertain whether the colouring matter of Prussian blue existed in the stone or in the sublimate before the application of heat, we examined each of these by mixing them with the alkali and green vitriol, but could not produce Prussian blue from either of them.

Wishing to know whether the residue of urine resembled the calculus in this respect, we introduced 380 grains of the incrustation upon walls, where people make water, into an earthen retort. The incrustation was so moist, as to stick in places to the neck of the retort. There came over a liquor of a light brown colour, which became darker, and then lighter, impregnated with alkali, which did not appear to be combined with prussic acid as was observed in subliming the stone. Paper, moistened with solutions of green vitriol and caustic alkali, was repeatedly presented to it during the whole operation, but no Prussian blue

could be formed. The fire was kindled at half an hour before eight o'clock, and at half an hour after one, neither air nor moisture came over, though the heat was very great. After the sublimation, the charry matter at the bottom of the retort weighed 78 grains. The helm of the retort was thinly incrusted with a black substance, of which we could collect only half a grain. There was nothing which resembled the sublimate of the stone.

Thus both the products and the residue from this kind of stone, and from the incrustation upon walls, differ very widely from each other.

A glass retort was charged with a considerable quantity of the residue after evaporating urine. Accidentally, the weight of it was not ascertained. It soon smoked in the fire, and gave over volatile alkali and fixed air, both in greater abundance than we observed in any other sublimation. The volatile alkali incrusted the lower part of the neck of the retort. After the opera-

tion had continued an hour and a half, inflammable air came over with the fixed air, and also a very small quantity of prussic acid. Three quarters of an hour after, a sublimate had formed in the neck of the retort, to which a strong heat being applied, air came over very rapidly, which seemed to be a mixture of the phlogisticated and inflammable airs. Paper moistened with a solution of green vitriol and of a fixed alkali, was instantly turned black upon being presented to these fumes; it then effervesced strongly with acid, the black disappeared, and it exhibited a very slight blue tint. The residue in the retort, after the operation, was 220 grains. The sublimate, partly black and partly white, weighed 3,5 grains; the white part was nearly 2,5 grains, and dissolved in the nitrous acid.

I cannot positively say, whether this small quantity of sublimate was the same with that which Scheele obtained from the calculus; nor indeed is it material. The quantity of this sublimate is so inconsider-

able, and the appearance of Prussian acid so trifling, comparatively with what we always observe when the stone which contains the sublimate of Scheele is strongly heated, that we may infer with safety, that the residue from urine, including the mucus commonly contained in it, possesses the elements of this kind of stone, which is I believe the most common, in very small proportion.

I was anxious to know whether the mucus of a calculous patient contained this sublimate in greater abundance than the urine, when I was interrupted, as I have already hinted, by discovering, that the stone itself of the patient, whose urine and mucus I proposed to compare, did not yield this sublimate. I had before observed, that this stone, and the dried mucus of the man from whom I obtained it, did not dissolve in alkalis. It consequently became a general question, whether other stones, not dissolving in alkalis, contained the sublimate of Scheele?

For the purpose of ascertaining this, we introduced into two small glass retorts twenty grains of a calculus, which had been almost, if not altogether, unaffected by lime-water and soap-lees, even assisted by heat, and an equal quantity of calculus, which had yielded the sublimate in a former experiment, and placed these two retorts on a level with each other, in a covered cast-iron stove, where we gave them a moderately strong heat.

The appearances were as follow.—From the former, that is, the stone which did not dissolve in alkalis, volatile alkali soon came over in abundance, and a watery liquor. No sublimate lined the neck of this retort. On introducing paper, moistened with the solutions of green vitriol and of the alkali, little or no blue appeared. At a second trial, the paper effervesced strongly with acids, but shewed no Prussian blue. At seven successive trials the appearances were the same. No sublimate was seen in the retort in any part of this operation:

the neck of the retort was just tinged a very little way with a thin film. The residue was sixteen grains.

From the latter, that is, the calculus which had yielded the sublimate in a former experiment, volatile alkali did not arise so soon. Brownish fumes soon filled the body of the retort; and a brown and white sublimate lined the neck to its very extremity, in great abundance. On introducing the paper, prepared as in the preceding experiments, much Prussian blue was discovered. At a second trial, a very great quantity of blue appeared, and no effervescence when the paper was dipped in acids. At four successive trials, the appearances were the same. At a sixth, seventh, eighth, and ninth trial, there was a slight effervescence upon the application of acids to the paper, and a very deep blue. The residue was not very accurately collected, and fell short of three grains. The sublimate was found in flakes in the neck of the retort.

The residue in one instance is about three grains, in the other sixteen. By this criterion alone we may readily distinguish the two kinds of stone, by exposing them to a red heat in open vessels, and weighing the residues. It is probable however, that they are not always so distinct: but that the proportion of the sublimate varies in different calculi.

Mr. Lane observed, at least twenty years ago, that the volatility of calculi bore some proportion to their solubility in alkalis. The existence of the sublimate, to which both these properties are owing, had been discovered a few years before.

The heat, in which Mr. Scheele produced the sublimate, was nearly the same as was applied in the above experiments; for he made use of a glass retort in this operation; and in all our experiments, when we used glass vessels, we applied as much heat as they would bear without fusion; indeed they were often actually melted. I presume, therefore, that as far as his tests of

the presence of the sublimate go, we have no proof whatever of its existence in one of these calculi. But the heat applied to those calculi, which Mr. Lane examined, was still greater: they were sent to Mr. Alchorne, assay-master, and were kept in his furnace from the lighting of the fire till the heat was sufficient for coppelling, which requires a strong red heat. It cannot be supposed that the sublimate, a substance so volatile, and so easily decomposed, could in any state of combination resist this degree of heat.

Lime-water acts upon the calculi, which contain the sublimate, in a very particular manner. During its first action, white spots appear upon the stone, and after a short time, fine clear crystals shoot like stars from different points of the stone. After standing a long time in the same liquor, these crystals become of an opake whitish colour, and break asunder. I have not always observed the appearance of crystals even in the same kind of calculi; but I did not fully ascertain the cause of this va-

riation. Dr. Whytt has taken notice of these crystals. Lime-water has the same effect upon the sublimate; and these crystals appear only, when those calculi which possess the sublimate, are mixed with lime-water: hence we may conclude, that either the entire sublimate, or something contained in it, is a constituent part of these crystals, and consequently necessary to their formation. This analogy in the operation of lime-water upon the stone and the sublimate seems to shew, that the latter is not merely a creature of the fire, or a modification of certain parts of the stone produced by heat, and which did not exist before the decomposition of the stone, but that it is actually present in the stone in the same state.

As the sublimate dissolves in the caustic alkalis, so also calculi containing the sublimate dissolve readily, and almost wholly, in the caustic alkalis; which, on the other hand, act but weakly upon those that do not contain the sublimate. These last, as

far as I have observed, and as may be collected from Doctor Dawson's paper in the Transactions of the College, are generally whiter than the rest.

With regard to the calculi which contain the sublimate, it has been already proved, that nothing could be discovered in urine, which accounted for their formation. Those, which do not contain it, have no peculiar character, by which they can be distinguished chemically from many other animal substances. Their colour affords some proof, that they are not formed from urine; because all residues and incrustations from urine are brown, with some tint of red or yellow. I dried the mucus of a man, from whom I had one of the calculi which was insoluble in alkalis, and found them to resemble each other in colour, and in a shining crystalline appearance. An incrustation from the urine of the same man was of a darker colour. The dried mucus also resembled this calculus, in not dissolving in alkalis, and in yielding readily to the nitrous acid.

The following experiments on the sublimate do not immediately relate to our present inquiry; but as they seem to extend our knowledge of this concrete, they will not, I hope, be unacceptable in this place.

Both the sublimates pruduced in the two former experiments being put into a glass retort, heat, applied by a lamp, drove up an argentine sublimate which crystallized in the neck of the retort, and at the same time a most pungent smell of volatile alkali. The retort was then suspended within a furnace in such a manner, that both the body and part of its neck received a strong heat. A white sublimate soon appeared low down in the tube, and that, which was higher up in the neck, appeared to bubble and turn black. Volatile alkali came over with the prussic acid, and a small quantity of air, which we found to be phlogisticated. On increasing the fire it was evident, that the sublimate which had risen was decomposed.

The prussic acid came over in abundance with a considerable quantity of phlogisticated air. After this, black fumes lined the neck of the retort to its extremity, and the smell of prussic acid was very strong. It was remarkable at this time, that, on applying a vegetable blue, it became red. Soon after, volatile alkali came over without any prussic acid that we could discover by the paper dipped in solutions of iron and alkali. Before the appearance of the black fumes above-mentioned, the water, in which the extremity of the tube was immersed, was sucked up, and dissolved the matter sublimed within the tube as high as it went. The heat being further augmented, prussic acid and volatile alkali again appeared. We continued the operation, till we conceived, that whatever sublimate was not decomposed, was driven down to that part of the neck of the retort, to which much heat could not be applied. On breaking the retort, we found the sublimate to consist of a dark

brown matter, which had melted and run down the neck of the retort; of a pale brown substance, which incrusted the higher parts of the neck; and of white shining spiculæ, which had formed, probably while the fire was going out, upon the inner surface of the pale brown sublimate.

Upon the whole, it appeared, that, when the heat was gentle, volatile alkali abounded; and when violent, that there arose little or no volatile alkali, but prussic acid and phlogisticated air.

We then put the matter, which had been twice sublimed, into a glass retort, and fixed it in the same furnace. On the application of a gentle heat, a pungent smell of volatile alkali was produced. Soon after, the prussic acid was detected coming over with it, and a small quantity of air. A white sublimate appeared, as before, in the neck of the retort, and the tube was covered with a dark crust, which arose in visible fumes.

The appearances were the same at each successive operation; we therefore judged

it fruitless to repeat the sublimations further, and undertook to examine the residue and the sublimate in a different manner.

We put ten grains of the matter which had undergone three sublimations, with two drachms of nitrous acid and a little distilled water, into a glass retort. An effervescence ensued, and we were soon able to catch a small measure of air. Lime-water being admitted to this air became turbid, and absorbed one-third part of it. To the remaining air we threw up an equal quantity of common air: no contraction appeared, and the mixed air immediately and totally extinguished a flaming match. Therefore the two-thirds of air, which were not absorbed by lime-water, were chiefly, if not altogether phlogisticated air.

The retort was then set on hot sand, and some air soon came over, which we were unable to catch. Afterwards nitrous acid distilled over. It was a considerable time before the whole of the sublimate dissolved, but it did dissolve perfectly. Upon

continuing the heat, a light brown sediment fell to the bottom of the liquor, and at the same time the nitrous acid evaporated. Air came over in small quantities, as the mass dried: at one time it made lime-water turbid, but not on a second trial. As soon as the charge was dry, we put it within the furnace, and gave it a strong heat. A white sublimate arose, and volatile alkali came over. The heat being further increased, some prussic acid was discovered; but at this time, we could perceive no fixed air. A grain or two of a light reddish brown powder remained in the retort.

Thus it appears, that even after solution in nitrous acid, the sublimate from the calculus retains its property of yielding caustic volatile alkali and prussic acid.

Lastly, we poured into the same retort, containing the residue and the sublimate, a few drops of nitrous acid. An effervescence immediately ensued, and a small quantity of air, which was unavoidably mixed with that of the vessels, was caught. One-tenth

part, or more, of this air was fixed air, and the remainder phlogisticated. The sublimate seemed to dissolve more readily than the residue; of which a great part, and also a small part of the sublimate, did not dissolve.

About seven grains of the sublimate immediately obtained from a calculus were then mixed with a small quantity of vitriolic acid. This mixture very soon turned black without the application of fire. When heat was applied, we obtained fixed air and common air first; then fixed air, with four-fifths or five-sixths of phlogisticated air; and, upon continuing the heat, an air, of which nine-tenths was fixed air. The sublimate was perfectly dissolved.

By this experiment we find, that the sublimate consists of heavy inflammable air and phlogisticated air; but when heat is applied to the sublimate alone, it is resolved into volatile alkali, or prussic acid and phlogisticated air. Would not this be impossible, unless the heavy inflammable air were com-

posed of the same elements as the volatile alkali, or prussic acid?

When heat was repeatedly applied to the calculous sublimate, there was always some residue after each operation. The residue, after the third sublimation, was of a brown colour, and of a light and spongy consistence. Of this we mixed two or three grains with half an ounce of vitriolic acid diluted with water. It immediately turned of a dark colour. We then heated it with burning paper in a small glass retort, till it boiled. After much of the air of the vessels was expelled, we caught a small quantity of air, one-fourth part of which was fixed air, and the remainder resembled common air. Thus it appears, that the residues do not differ essentially from the sublimates themselves; and that when, by the application of fire, the sublimate is resolved into volatile alkali and phlogisticated air, or into prussic acid and phlogisticated air, and a residue is left, the residue, like the sublimate itself, is still capable of yield-

ing inflammable air by this method of treatment.

It would not be difficult to decompose every particle of any given quantity of the sublimate in this manner: but the experiments already described leave little room for doubt concerning the composition of it. And indeed the ultimate analysis of this sublimate is an object deserving only a secondary attention, while the art of dissolving the stone itself, in such a manner as to assist those who linger under it, is yet imperfect. The experiments, which point out the distinctions of calculi, explain the reason, why our curative attempts have so often failed, and likewise prove, that they must always fail, at least in those calculi which do not contain the sublimate, so long as alkaline menstrua alone are employed. In this state of medicine, those, who suffer this species of the disorder, must either bear it for life, or submit to a dreadful alternative, to an operation, which few surgeons ever acquire the art of performing dex-

terously, and which, performed even by the most skilful, is by far the most dangerous of any that is practised in surgery.

THE END.

ERRATA.

P. 5. l. 1. and in several other places, for *prostrate* read *prostate*.

P. 115. l. 7. for *pruduced* read *produced*.